NASA White Sands Test Facility

# *Electrical Arc Ignition Testing of Spacesuit Materials*

October 2006

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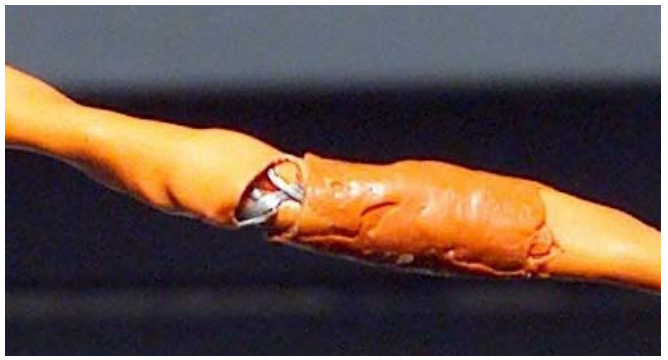
# *Background*

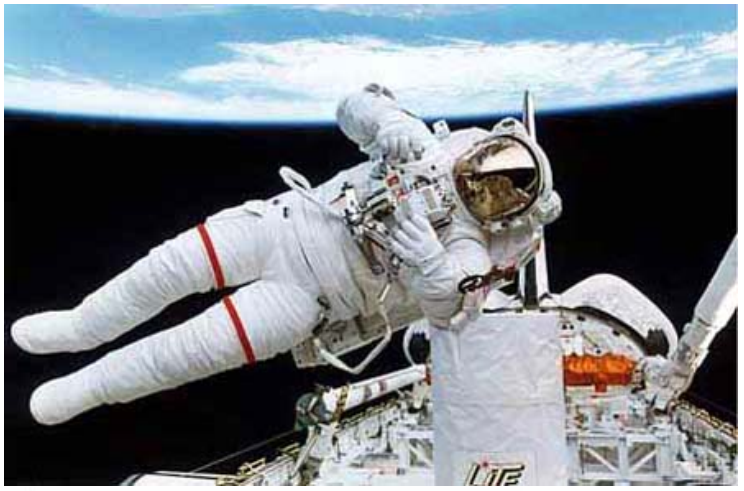
- Testing in response to frayed cable discovered during spacewalk
- Reliance on Apollo-era arc testing
  - Limited applicability to current materials
  - Significant changes in voltage and circuitry
  - Poor understanding of test configuration

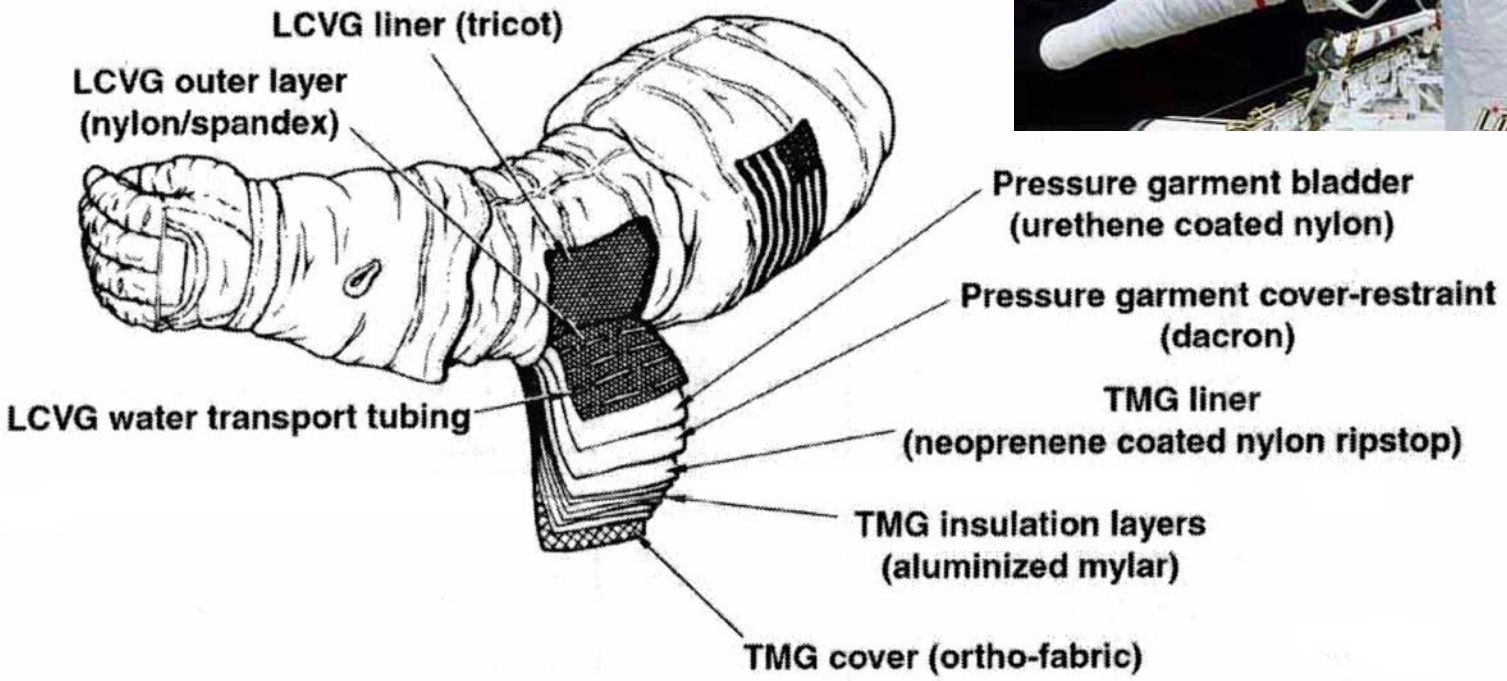


# *Test Objectives*

- Gain better understanding of Apollo-era data
- Investigate new test methods
- Characterize minimum current levels necessary for combustion of EMU materials (at a given voltage)

# *Test Sample Materials*





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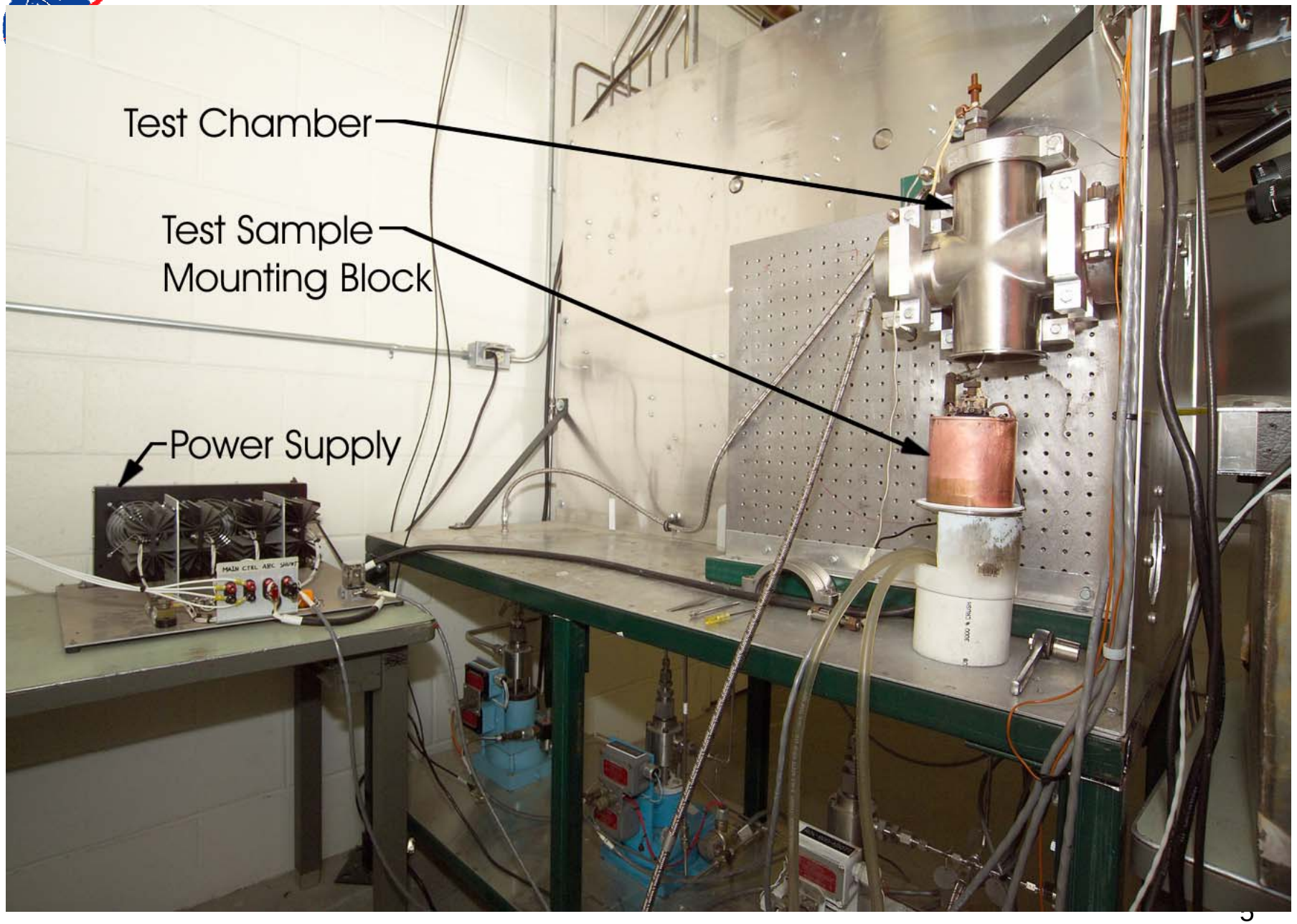
Test Chamber
Test Sample
Mounting Block
Power Supply

# *Test Methods*

- Multiple location intermittent arcing (scratch) test
- Single location intermittent arcing (poke) test
- Single location wire-break arcing test

# *Scratch Test Objectives*

- Simulate Apollo-era testing
- Determine configurational effects
- Test materials currently used in the EMU



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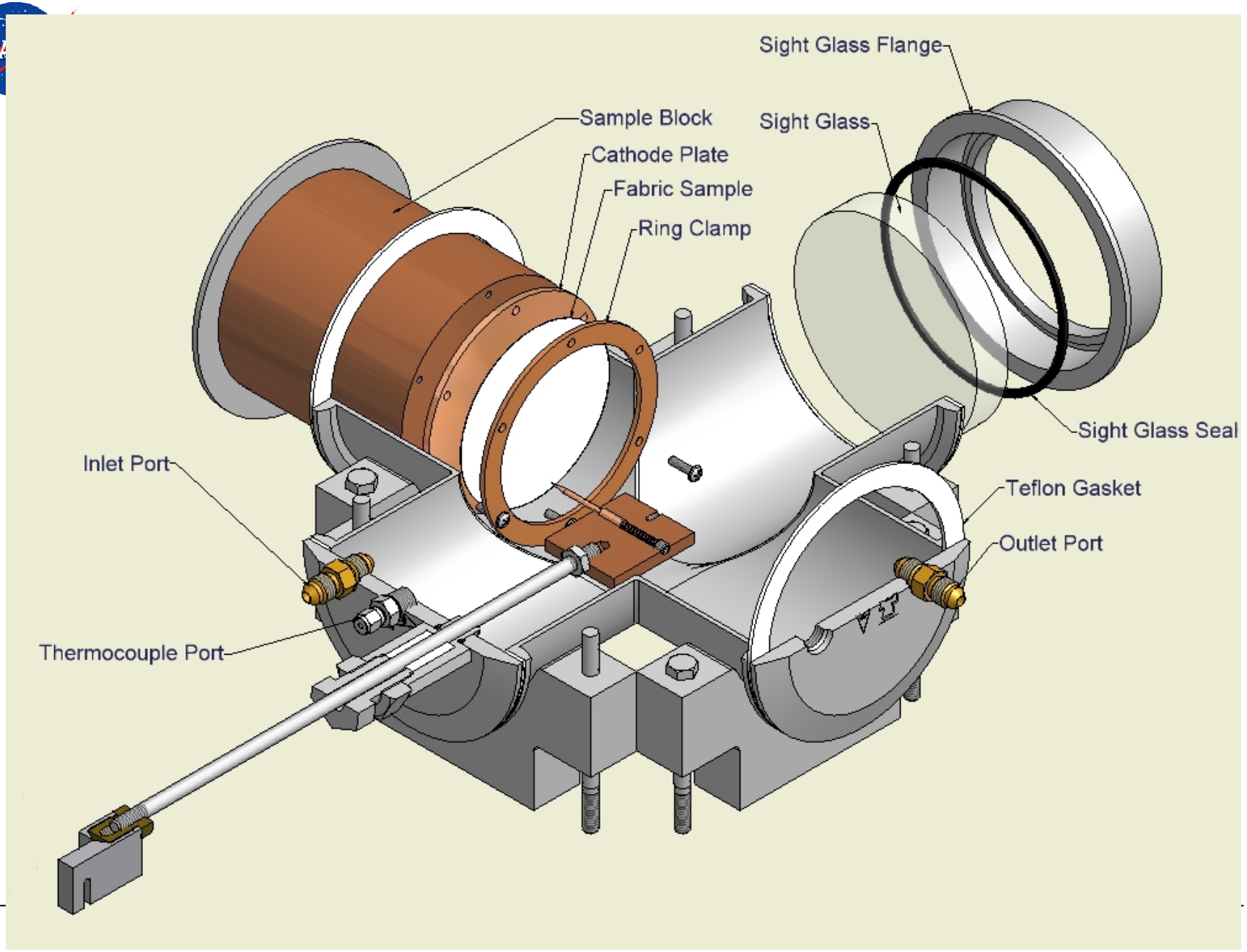
Sight Glass Flange
Sample Block
Sight Glass
Cathode Plate
Fabric Sample
Ring Clamp
Sight Glass Seal
Inlet Port
Teflon Gasket
Outlet Port
Thermocouple Port

# Cotton Scratch Test Video




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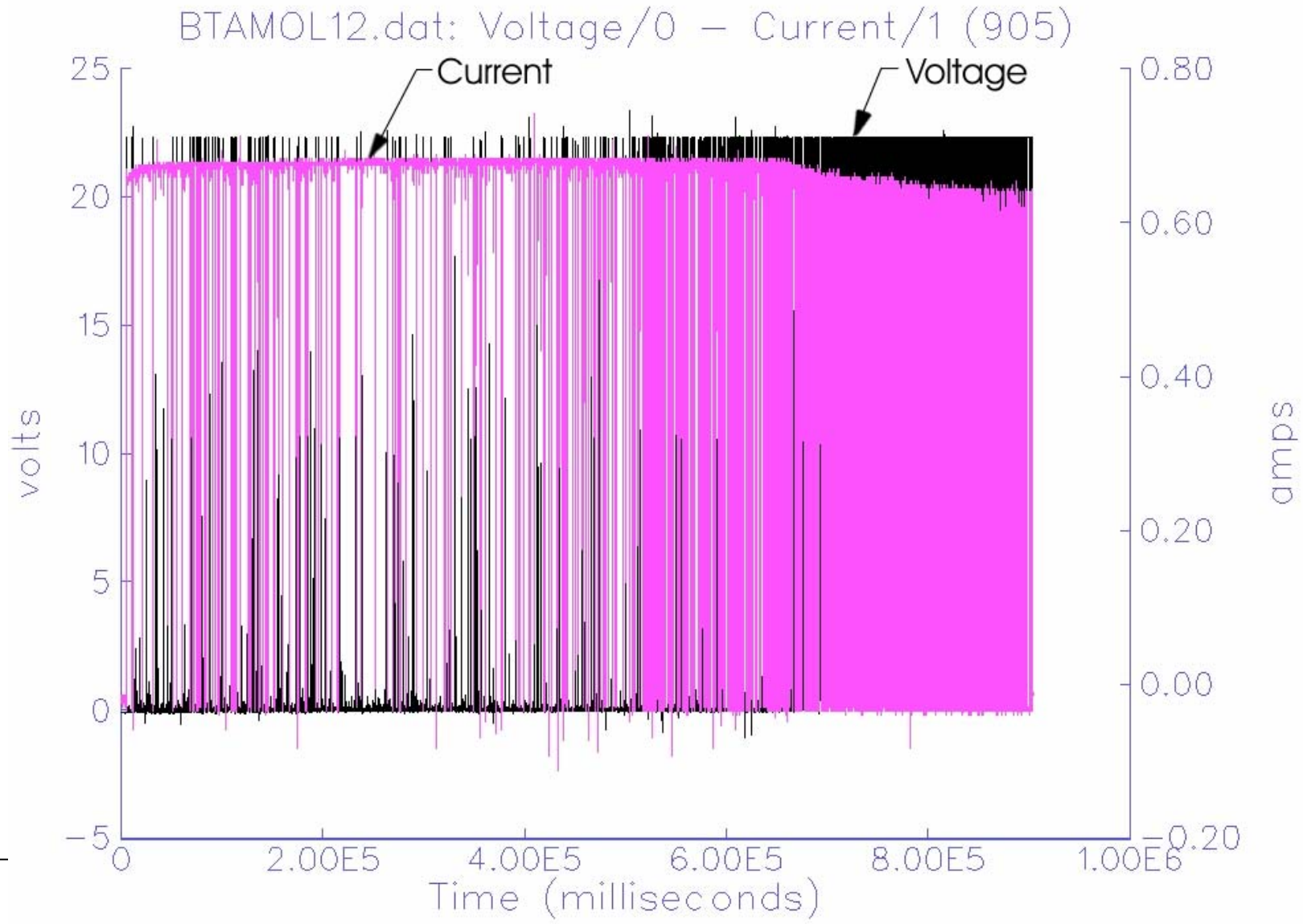
# *Scratch Test Results*

- Testing yielded results similar to Apollo-era testing
- Frayed materials more reactive
- No distinguishable difference between horizontal samples and vertical samples
- Tests performed at 23.5 psia 100% O2, 22.5 V
  - 7 materials tested
  - Current required for ignition ranged from 0.8 A to 1.4 A

# Entire Data Plot



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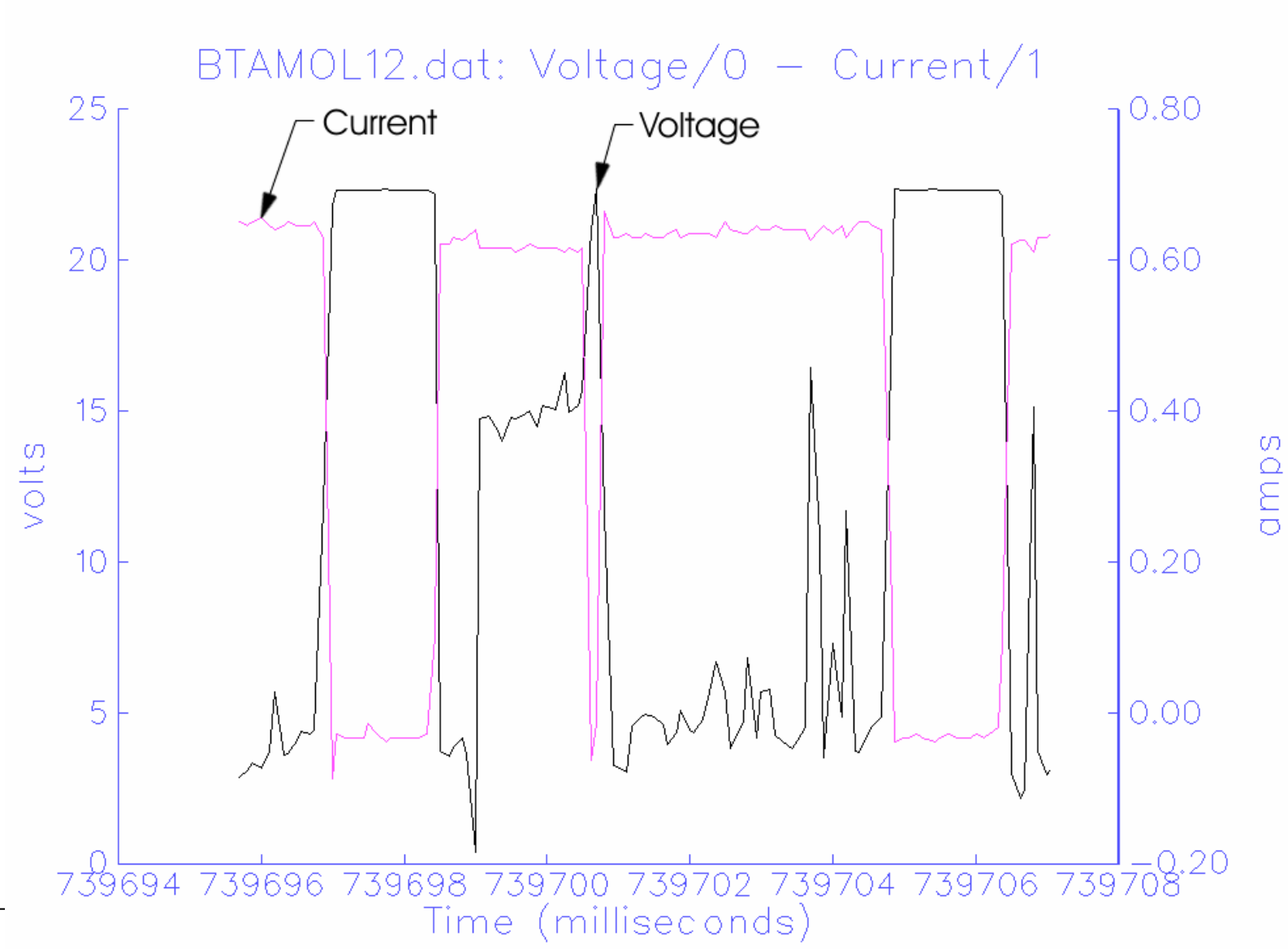
# Closeup Data Plot





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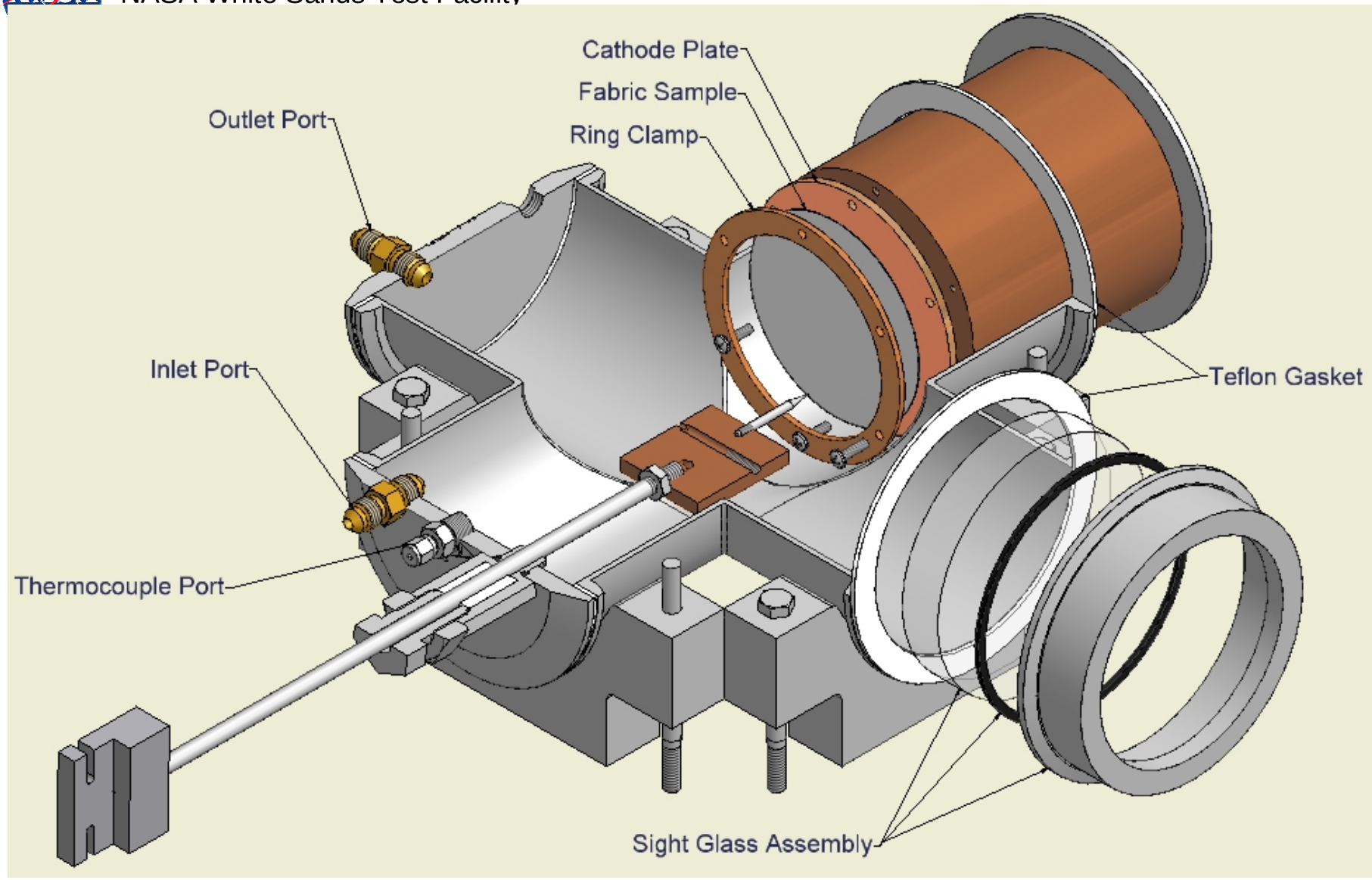
# *Scratch Test Problems*

- Not possible to determine which arc ignited material
- Arc energies vary widely from test to test and arc to arc
- Difficult to ensure that test sample material is in intimate contact with arcing event
- Configuration not realistic for inside spacesuit because of size of stylus

# *Poke Test Objectives*

- Determine whether more severe to arc with wires or stylus
- Determine whether more severe to arc in single location (poke test) or multiple locations (scratch test)


Cathode Plate
Fabric Sample
Ring Clamp
Outlet Port
Inlet Port
Thermocouple Port
Teflon Gasket
Sight Glass Assembly



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# *Poke Test Results*

- Poke test results consistent with scratch test results
  - No detectable difference between arcing in one location or multiple locations
- Tests showed that it is more severe to arc with a wire than a stylus
  - Wires are flammable and can burn in oxygen
  - Burning wires easily ignite test materials



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# *Poke Test Problems*

- Not possible to determine which arc ignited material
- Arc energies vary widely from test to test and arc to arc
- Difficult to ensure that test sample material is in intimate contact with arcing event

# *Wire-break Test Objectives*

- Reduce variability in tests
- Test all materials
- Determine whether ignition is dependent on voltage or current



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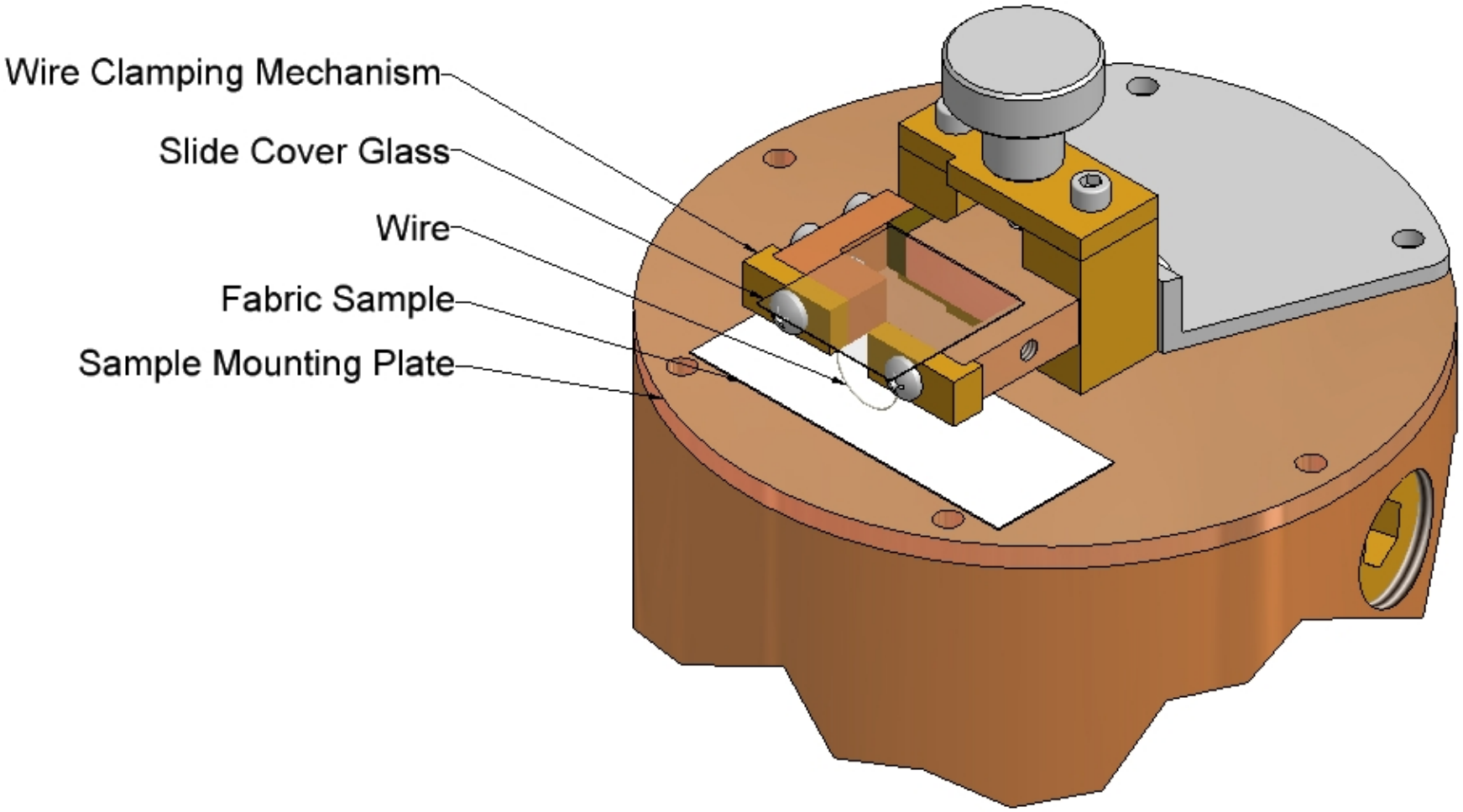
Wire Clamping Mechanism
Slide Cover Glass
Wire
Fabric Sample
Sample Mounting Plate



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| AWG Size | Diameter (in.) | % of Flight Wire Cross Sectional Area | Approximate Current Required to Break Wire (A) |
|---|---|---|---|
| 34 | 0.0063 | 1550 | 9.00 |
| 38 | 0.004 | 625 | 5.00 |
| 39 | 0.0035 | 479 | 3.80 |
| 40 | 0.0031 | 375 | 3.00 |
| 41 | 0.0028 | 306 | 2.60 |
| 42 | 0.0025 | 244 | 2.30 |
| 43 | 0.0022 | 189 | 1.80 |
| 44 | 0.002 | 156 | 1.50 |
| 45 | 0.0018 | 127 | 1.30 |
| **46** | **0.0016** | **100** | 1.10 |
| 47 | 0.0014 | 77 | 0.90 |
| 48 | 0.0012 | 56 | 0.83 |
| 49 | 0.0011 | 47 | 0.70 |
| 50 | 0.001 | 39 | 0.63 |
| 51 | 0.00088 | 30 | 0.50 |
| 52 | 0.00078 | 24 | 0.45 |
| 54 | 0.00062 | 15 | 0.35 |

# *Cotton Wire-Break Test Video*



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# *High Speed Cotton Wire-break Test Video*




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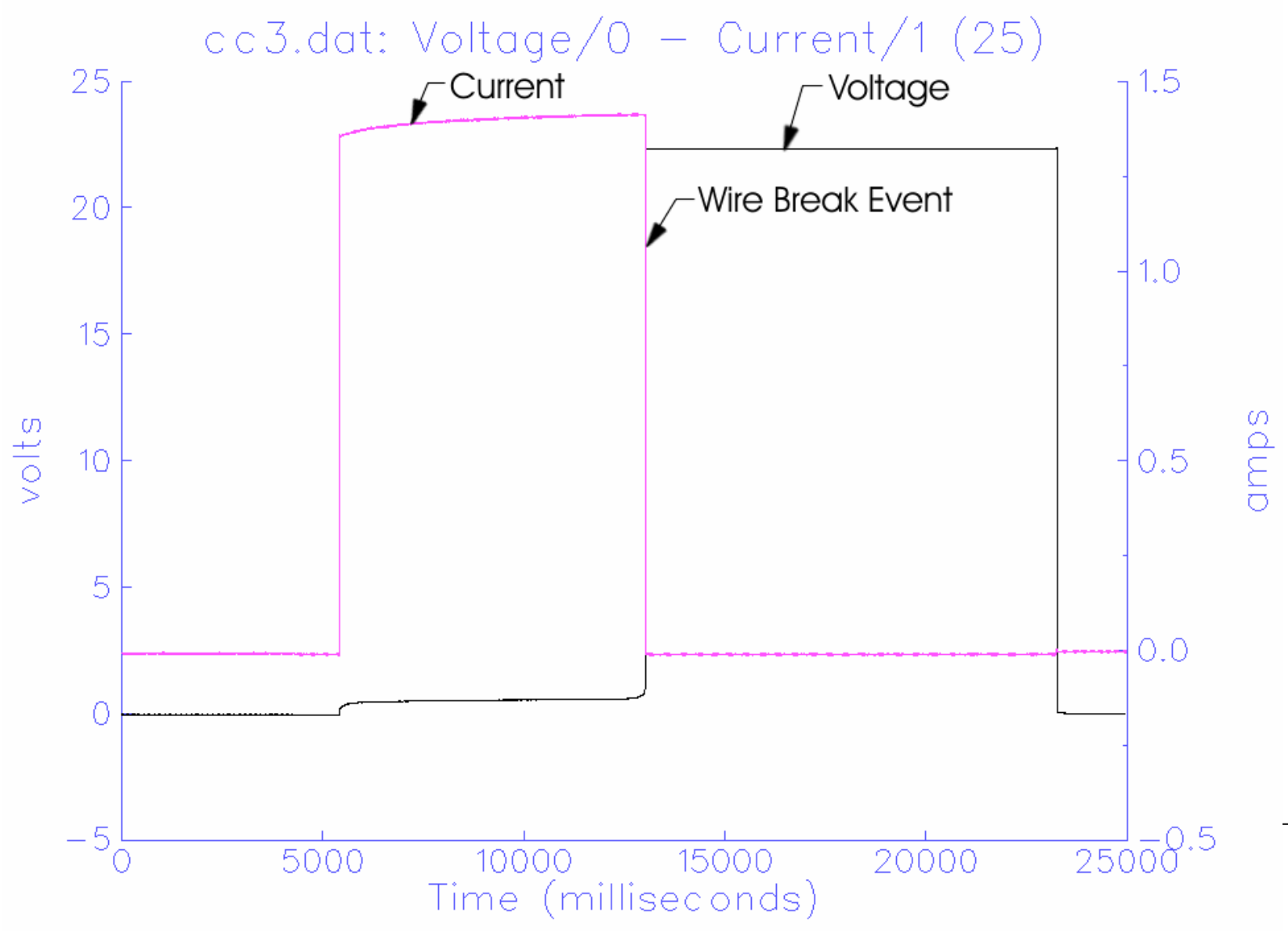
# Typical Data Plot



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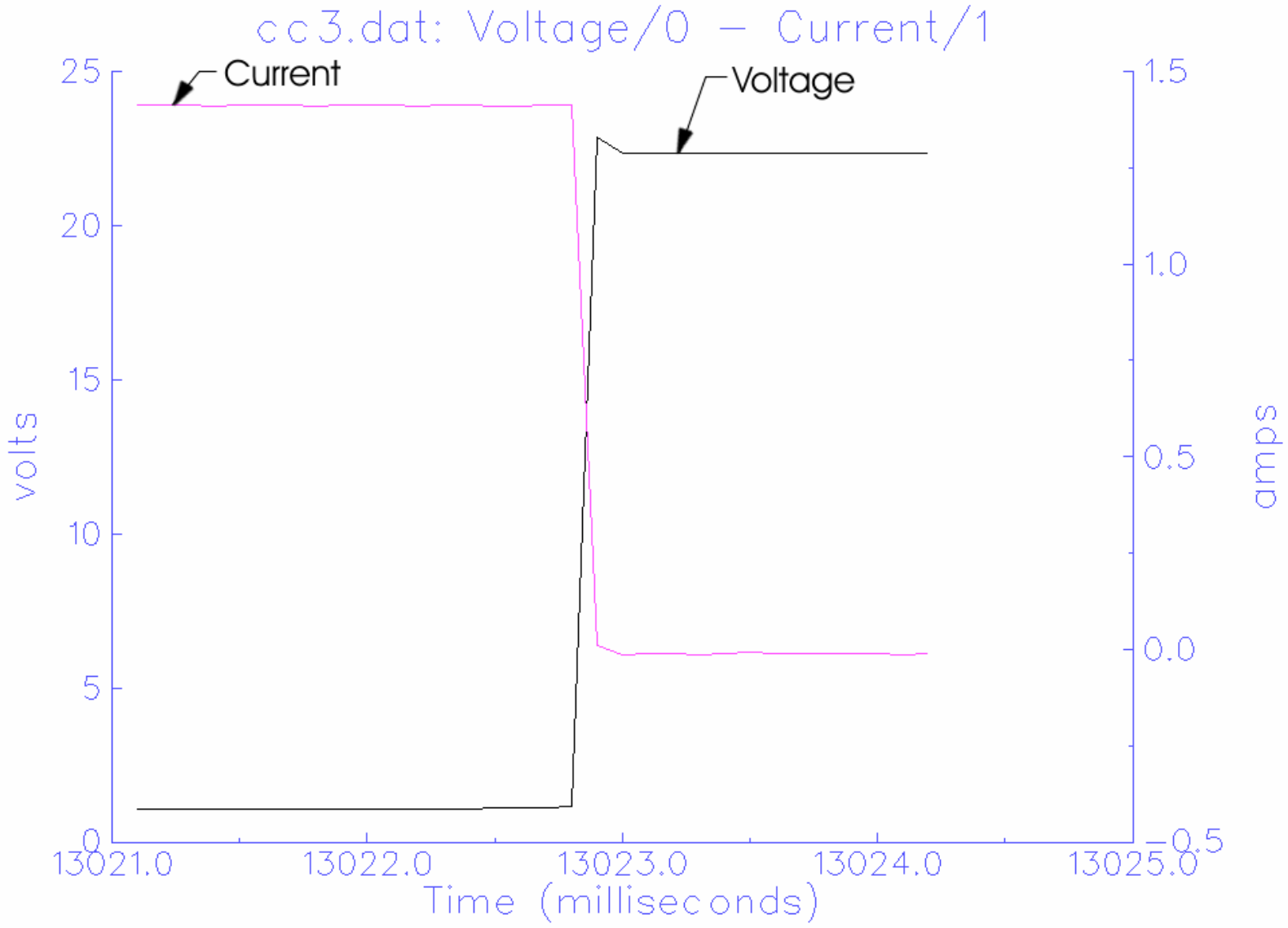
# Closeup Data Plot



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# *Wire-break Test Results*

- Much more severe than scratch and poke tests
- Test conditions
  - 23.5 psia 100% O2, 22.5 V
  - 50 psia 50% O2 and 50% N2, 15 V
- Several materials failed testing at the lowest possible current, ~0.3 A
- Current required for ignition for most materials ranged from <0.3 A to 0.97 A

# *Wire-Break Test Results (cont.)*

- Gore-Tex only ignited under much more severe conditions
  - 100% O2, 54 psia
  - Zigzag wire configuration



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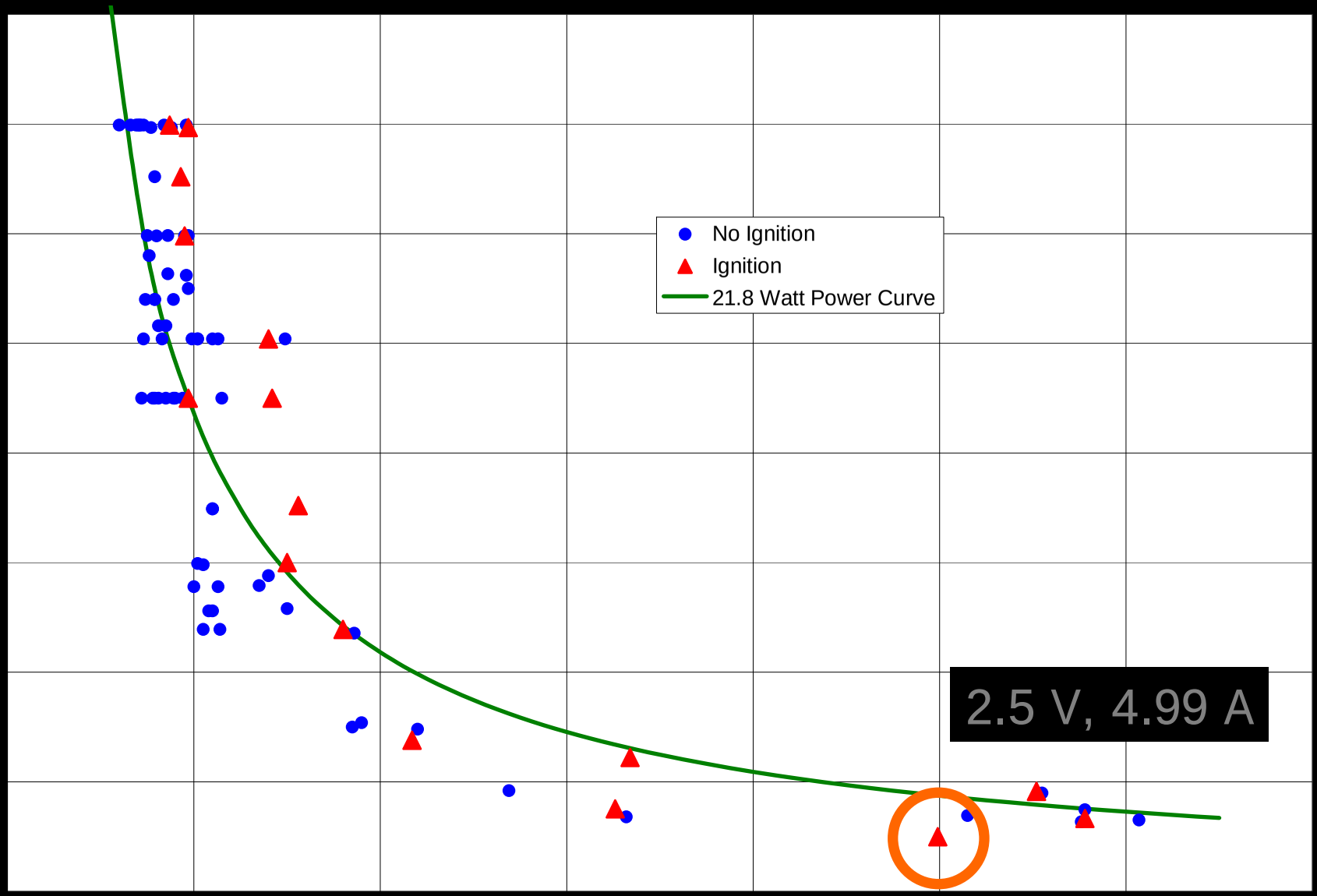
# *Wire-break Tests vs. Scratch Tests*

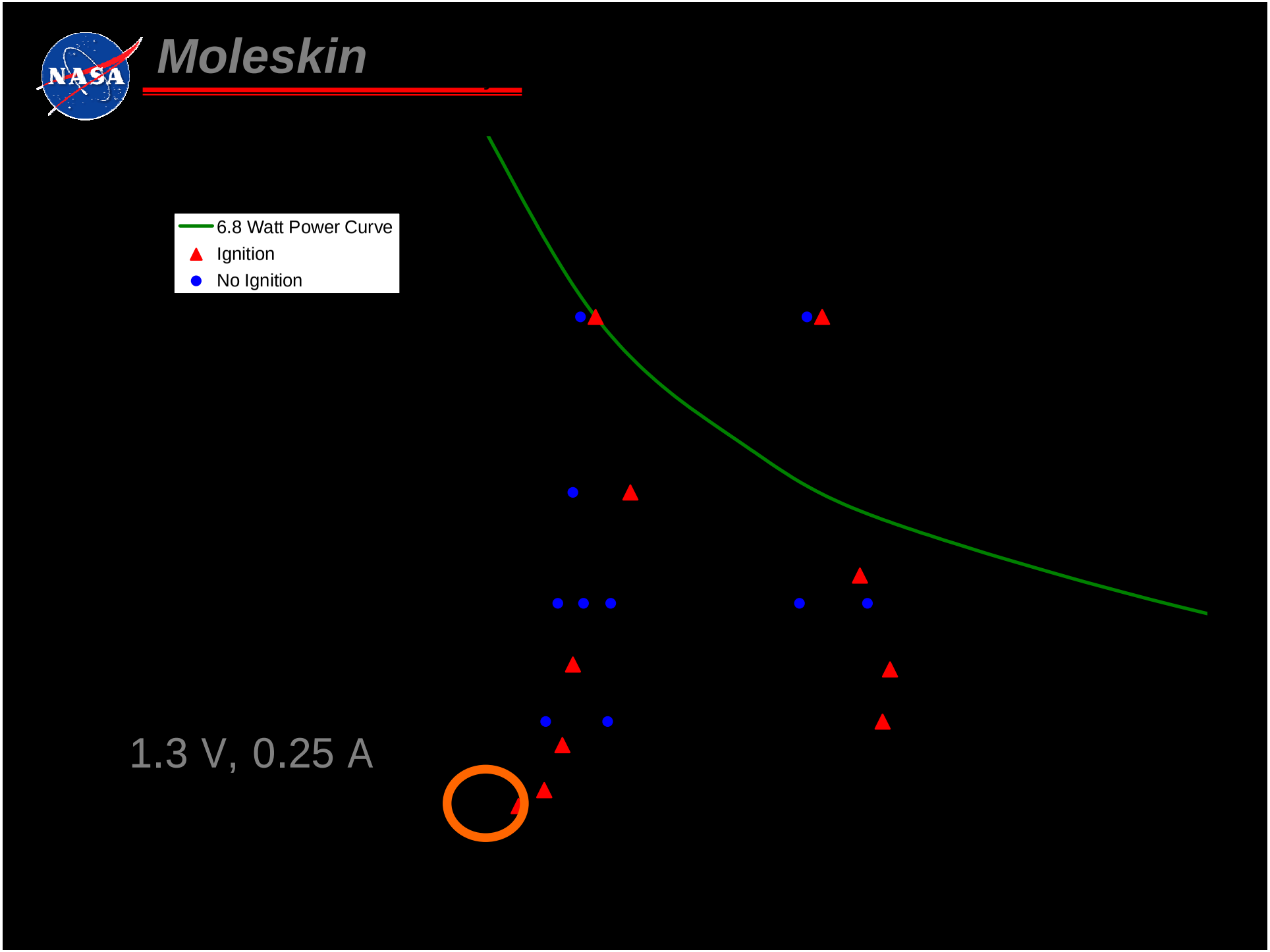
## 23.5 psia 100% O2, 22.5 V

| Material | Wire Test Available Current at Ignition (A) | Scratch Test Available Current at Ignition (A) |
|---|---|---|
| Generic cotton | 0.36 | 0.95 |
| Moleskin | 0.3 | 0.8 |
| UCN (shiny side) | 0.70 | 1.4 |
| Nylon/Lycra Comm Cap | 0.59 | 1.3 |
| Astronaut undergarment | 0.64 | 1.4 |
| LCVG spandex | 0.53 | 1.4 |
| LCVG tricot | 0.49 | 1.3 |

# Urethane-coated Nylon



# Moleskin



| | Material | Surface Characteristics |
|---|---|---|
| Best | Interface cable Gore-Tex® sleeve | Smooth |
| | Urethane-coated nylon suit bladder (fabric side) | Smooth |
| | PVC | Smooth |
| | Interface cable polyurethane jacket | Smooth |
| | Urethane-coated nylon suit bladder (shiny side) | Smooth |
| | Astronaut longhandle undergarment | Fuzzy |
| | CCA cap spandex (nylon & Lycra® knit fabric) | Smooth |
| | LCVG garment (multifilament nylon / spandex knit 1106 treated with 3% TCHDE solution) | Smooth |
| | LCVG garment inner liner (nylon tricot treated with 3% TCHDE solution) | Smooth |
| | Cotton flocked Rucothane® glove bladder | Fuzzy |
| | TCU assembly (Capilene® – hollow fiber polyester treated with 3% TCHDE solution) (gray) | Fuzzy |
| | Kerlix dressing | Fuzzy |
| | Generic cotton | Fuzzy |
| Worst | Moleskin | Fuzzy |

# *Conclusions*

- Wire-break test is worst-case
- Fuzzy materials generally easier to ignite
- Current appears to have greater effect than voltage
- Controlling risk must include both
  - Physical isolation of easy to ignite materials
  - Limiting current and voltage



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